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Department of
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Forest
Service

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Reply To: 3420

Date:

Subject: FPM Biological Evaluation of Insect and Disease Conditions on the East Shore of Lake Tahoe (Report No. C93-10)

To: Forest Supervisor, LTBMU

Please find enclosed a report from the Forest Pest Management (FPM) South Sierra Shared Service Area. The report documents findings from a biological evaluation conducted May 18-19, 1993 in the Secret Harbor, Slaughterhouse Canyon and Skunk Harbor areas on the east shore of Lake Tahoe. Over the past few years, the LTBMU has experienced exceptionally high levels of conifer mortality due primarily to interactions between drought stress, stand conditions, and an insect and disease complex that includes the Jeffrey pine beetle, the fir engraver, the mountain pine beetle and dwarf mistletoe. Potential insect and disease management alternatives are discussed, including control of the Jeffrey pine beetle and dwarf mistletoe.

Please direct any questions to John Wenz or John Pronos at (209) 532-3671.

JANET L. WOLD
Forest Supervisor

FOREST PEST MANAGEMENT
Pacific Southwest Region

Report No. C93-10

3420
July 27, 1993

Evaluation of Insect and Disease Conditions in the Secret Harbor, Slaughterhouse Canyon and Skunk Harbor Areas on the East Shore of Lake Tahoe.

John M. Wenz, Entomologist
John Pronos, Plant Pathologist

BACKGROUND

In response to a request from the Lake Tahoe Basin Management Unit (ref. 3420/2400 memo, 6 May 1993), John Wenz, Entomologist, and John Pronos, Plant Pathologist, Forest Pest Management (FPM) South Sierra Shared Service Area, conducted an evaluation on May 18-19, 1993, of areas along the east shore of Lake Tahoe. The LTBMU has observed a dramatic increase in Jeffrey pine beetle-related mortality over the past few years on the east side. Many of the Jeffrey pine stands are also infected with varying levels of dwarf mistletoe. Several of these areas are of particular concern to the Basin because of high public use and the presence of high value developed campgrounds and resorts. The specific areas covered by this evaluation were the Secret Harbor (T15N, R18E, parts of S11,14,23,26) and Slaughterhouse Canyon-Skunk Harbor (T15N, R18E, parts of S26, 27, 34, 35 and T14N, R18E, parts of S2, 3) areas, identified as Priority I and Priority II, respectively, by the Basin. The objectives of the evaluation were to identify the important insects and diseases active in the two areas and provide pest management alternatives for consideration by the LTBMU in determining appropriate resource management action.

SECRET HARBOR

Observations - Stands in the Secret Harbor area are mixed conifer and tend to be multi-storied. The overstory is approximately 140 years old and consists primarily of Jeffrey pine with some incense-cedar, white fir and a few sugar pine. Intermediate layers are mainly incense-cedar and white fir with some Jeffrey pine. The regeneration is mostly white fir with some incense-cedar. Ground cover is primarily manzanita and antelope bitterbrush with some chinquapin. Coniferous stocking is variable throughout the area ranging from <100 sq.ft./ac to >340 sq. ft./ac. Several small (< 1/2-acre) openings,

usually heavy to brush, were present. Above normal mortality, both past (over the last 3 to 4 years) and current, is evident throughout the area in all vegetative layers. Following is a discussion of the insects and pathogens observed in the area.

Insects: Bark and engraver beetles were the most important insects currently affecting the vegetation in the area; no significant defoliator activity or damage was observed.

a) Jeffrey pine beetle (JPB), Dendroctonus jeffreyi (Coleoptera: Scolytidae). The JPB was associated with the very high levels of Jeffrey pine mortality present throughout the area (see Appendix I for selected insect and disease biologies). The red turpentine beetle, D. valens, was found attacking the base of many JPB-infested Jeffrey pine. The emarginate ips, Ips emarginatus, was also found in the lower bole of JPB-attacked trees. Neither of the later two species were observed causing mortality on their own but rather were associated secondarily with JPB killed pines. A woodborer, probably the California flatheaded borer, Melanophila californica (Coleoptera: Buprestidae), was also found secondarily infesting trees killed by the JPB.

Current (1992-93 JPB generation) Jeffrey pine mortality occurred as large, overmature, individual pines, small, 2-5 tree mortality groups, and as large group kills of up to 24 trees. Three of the larger group kills consisted of 15, 23 and 24 currently infested trees. These trees contained JPB brood (larvae and adults with some pupae) resulting from attacks in the summer/fall of 1992. Diameters of attacked trees in these three groups ranged from 16" to 30" DBH. Basal areas of the groups varied from 280 sq.ft./ac to 340 sq.ft./ac. Although some slight crown fade was seen, many of these infested trees still had green crowns. Many, but not all, of the trees had Hawksworth dwarf mistletoe ratings of 4+. Each of three mortality groups was characterized by having older dead trees in the immediate vicinity of the currently infested pines. The number of older dead associated with these mortality groups ranged from 2 to 7. These trees had been attacked and killed by the 1990-91 or the 1991-92 JPB generation. The crowns of the older dead were faded, but there was at least some needle retention on trees that were probably attacked during the summer of 1991.

At least 8 trees in the immediate vicinity of the parking area had been extensively infested by the JPB. The largest of the trees were 22"-26" DBH and the crowns were just starting to fade from the bottom up. Upon examination, it was found that beetles had already emerged from the trees in the summer/fall of 1992. It is somewhat uncharacteristic that JPB-infested trees would (1) remain green for so long after adult emergence and (2) that they would fade from the bottom up. No diseases were observed that would account for the symptoms.

b) Fir engraver, Scolytus ventralis (Coleoptera: Scolytidae). The fir engraver was associated with mortality, top-kill, and branch dieback, of white fir in the area. Although some of the older,

overstory fir were affected, considerable damage to the fir in the intermediate crown classes was evident. The relatively high levels of fir mortality/ top-kill have been observed in the area (and throughout most of the Basin) for at least 4 to 6 years. Foliage is being retained on dead trees for up to 3 years.

Diseases:

a) Western dwarf mistletoe, caused by Arceuthobium campylopodum, is at moderate to severe levels in almost all of the area. Most Jeffrey pines had prominent witches' brooms and ratings of 4 or more using the Hawksworth 6-Class Rating System. The majority of heavily infected pines are showing symptoms of serious decline. This intensity of mistletoe infection is certainly playing a significant part in stressing trees and predisposing them to Jeffrey pine beetle attacks. Ponderosa and Jeffrey pines are the principal hosts of this pathogen in the Sierra Nevada; incense-cedar, white fir, and sugar pine are not affected.

b) Incense-cedar true mistletoe (Phoradendron juniperinum subsp. libocedri) infections were moderate to heavy at several locations, but not distributed throughout the area. This form of mistletoe is not as damaging as dwarf mistletoe on pines, but is still serious enough at Secret Harbor to be causing a gradual decline in the health of infected cedars. Because true mistletoe seeds are spread primarily by birds, control options are very limited and usually effective for only short periods of time.

SLAUGHTERHOUSE CANYON-SKUNK HARBOR

Observations. Vegetation in this area is variable, but generally similar to that described for the Secret Harbor area. The main difference is the riparian vegetation along Slaughterhouse Creek and the lodgepole pine stands that have developed on the more mesic, meadow, areas in Slaughterhouse Canyon. Relatively high levels of mortality, primarily involving Jeffrey and lodgepole pine and white fir, have been occurring over the past 3 to 5 years.

Insects.

With the exception of the mountain pine beetle (MPB), D. ponderosae, the insects of importance are the same as for the Secret Harbor area. The MPB was associated with both the lodgepole pine mortality and the relatively low, scattered, sugar pine mortality observed in both areas.

Very high levels of Jeffrey pine mortality were present on the east side of Slaughterhouse Canyon. One large group examined consisted of 27 currently infested Jeffrey pine. The basal area in the group ranged from 280 sq.ft./ac to 360 sq.ft./ac with diameters varying between 10" and 40" DBH. A number of faded trees with varying degrees of foliage retention, attacked by the 1990-91 and 1991-92 JPB generations, were observed in the immediate vicinity of the currently

understory fir were affected, considerable damage to the fir in the intermediate crown classes was evident. Substantially high levels of fir mortality/ top-kill have been observed in the fir stand (westernmost of the basin) for at least 4 to 5 years. Foliage is being retained on dead trees for up to 2 years.

Diseases

a) Western dwarf mistletoe, caused by *Arceuthobium campylopodum*, is at moderate to severe levels in almost all of the area. Most Jeffrey pines had prominent witches' brooms and ratings of 4 or more using the Hawksworth 6-class Rating System. The majority of heavily infected pines are showing symptoms of serious decline. This intensity of mistletoe infection is certainly playing a significant part in stressing trees and predisposing them to Jeffrey pine beetle attacks. Ponderosa and Jeffrey pines are the principal hosts of this pathogen in the Sierra Nevada; incense-cedar, white fir, and sugar pine are not affected.

b) Incense-cedar true mistletoe (*Phoradendron juniperinum* ssp. *libocedri*). Infections were moderate to heavy at several locations, and patchily distributed throughout the area. This leafy mistletoe is not as damaging as dwarf mistletoe on pines, but is still serious enough as a stress factor to be causing a gradual decline in the infected incense-cedars. Because true mistletoe seeds are spread primarily by birds, control options are very limited and usually effective for only short periods of time.

SLAUGHTERHOUSE ([illegible]) AREA

Description. Vegetation in this area is variable, but generally similar to that described for the Secret Harbor area. The main difference is the riparian vegetation along Slaughterhouse Creek and the lodgepole pine stands that have developed in the more mesic, meadow, areas in Slaughterhouse Canyon. Relatively high levels of mortality, primarily involving Jeffrey and lodgepole pine and white fir, have been occurring over the past 3 to 4 years.

Insects

With the exception of the mountain pine beetle (MPB) (*D. ponderosae*), the insects of importance are the same as for the Secret Harbor area. The MPB was associated with both the lodgepole pine mortality and the relatively low, scattered, sugar pine mortality observed in both areas.

Very high levels of Jeffrey pine mortality were present on the east side of Slaughterhouse Canyon. One large group examined contained 20 recently infested Jeffrey pine. The basal area in the group ranged from 150 sq.ft./ac to 250 sq.ft./ac with diameters varying between 15" and 40" DBH. A number of Jeffrey pines with varying degrees of foliage retention, attacked by the 1990-91 and 1991-92 JPB generations, were observed in the immediate vicinity of the currently

infested pines. In addition, an adjacent opening containing a few standing trees with no foliage and many downed, older, boles and large limbs, indicated that JPB had been active in that particular location for 4 to 6 years.

Another Jeffrey pine group kill was examined on a west facing slope near Skunk Harbor. This group consisted of 23 pines killed by the 1990-91 and 1991-92 JPB generations. Several of these trees exhibited fresh conks of the pouch fungus, Cryptoporus volvatus, and most had good needle (brown) retention. Only 7 currently infested Jeffrey pine were found but mortality over the past 3 to 4 years had killed virtually all the Jeffrey pine in the aggregation, leaving primarily white fir and incense cedar. Dwarf mistletoe was at low levels in this particular location. Another large Jeffrey pine group kill was located 70 to 90 meters from this group kill; here, Jeffrey pine was still a large component of the stand.

Diseases:

a) Western dwarf mistletoe was present but not widely distributed within the area. Infections levels were generally light and much lower than were encountered at Secret Harbor. There did not appear to be a strong correlation between dwarf mistletoe infection level and JPB attack in the Slaughterhouse Canyon-Skunk Harbor area.

b) Elytroderma needle disease (Elytroderma deformans) was scattered sporadically along Slaughterhouse Creek on Jeffrey pines. Infections were light and rarely involved more than 10% of the live crown. This amount of needle disease is minor and does not, by itself, warrant any direct action at this time, but should be monitored to detect any future increases.

MANAGEMENT ALTERNATIVES

The following insect and disease management alternatives are applicable to both the Secret Harbor and Slaughterhouse Canyon-Skunk Harbor evaluation areas. The discussion includes a description of what the likely insect and disease effects on the vegetation are under each alternative but are not intended to determine what the impact of those effects are (i.e., what the effects mean in terms of management objectives such as wildlife, dispersed and developed recreation and fuels management). The alternatives are intended for consideration within the context of LTBMU management objectives and constraints.

1. No Management. The above normal bark and engraver beetle-related mortality experienced in the two areas evaluated and throughout the Lake Tahoe Basin over the past 2 to 4 years is due primarily to a combination of (a) the extended drought, (b) diseases and (c) stand conditions. These factors have interacted to weaken trees to the extent that they are increasingly susceptible to successful bark and engraver beetle attack. A continued return to normal precipitation should, over the next 1 to 3 years, help

reduce the very high, extensive, levels of mortality induced by drought stress.

However, with no action directed at reducing or mitigating the other contributing factors, it is likely that relatively high levels of mortality will continue on perhaps a somewhat more localized, periodic, basis. JPB-related mortality to Jeffrey pine will result in (a) increased proportions of fir (see below) and particularly incense-cedar in Secret Harbor/Skunk Harbor mixed conifer stands, and (b) variable sized openings of up to about 1/4 to 1/2 acre (particularly in areas like the west side of Slaughterhouse Canyon with a high proportion of Jeffrey pine). Such openings are likely to be invaded by brush. The mortality will result in an increase in the amount of standing dead and down woody material which may have consequences relative to (a) the need/opportunity for salvage, (b) increased fuel loading, (c) increased wildlife habitat and nutrient cycling and (d), depending on location, the creation of hazardous trees.

Through time, increased amounts of true fir will create increased suitable habitat for the fir engraver. As evidenced by experience in similar stands in other areas in the central Sierra Nevada and northeastern California, unless appropriately managed, such conditions will likely result in continued above normal levels of fir engraver-related mortality and top-kill with effects similar to those described above for the JPB.

Dwarf mistletoe will continue to spread and intensify (as long as hosts are available) thus continuing to predispose trees to bark beetle attack and infect regeneration. Many Jeffrey pines are so heavily infected that a return to normal precipitation may delay their decline and death, but will not guarantee their survival. True mistletoe also will continue to have a negative effect on the health of incense-cedar.

2. Bark/Engraver Beetle Management

The following bark and engraver beetle management options are available for consideration: (A) direct suppression; (B) regulation of stocking; (C) sanitation/disease management and (D) slash management.

A) DIRECT SUPPRESSION. Under most circumstances in California, there are no biologically effective, economically feasible, environmentally acceptable direct suppression methods for bark beetles that are consistently effective in controlling area-wide populations such that subsequent tree mortality is reduced to acceptable levels. However, based on the factors discussed below, direct suppression of JPB populations through the harvest and removal of infested trees appears effective, at this time, in reducing subsequent mortality.

1) Circumstantial evidence from previous direct suppression projects on the LTBMU. A JPB suppression project (killing JPB brood by de-barking infested trees) was conducted annually over 165 acres between 1982-1987 in the Fallen Leaf Campground-South Shore Estates Recreation area. During the project, annual JPB-related mortality declined from 330 trees in 1982 to 4 in

1987. Jeffrey pine mortality remained at low, acceptable, levels until 1991-92, when mortality again started to increase, largely in response to drought stress. The LTBMU conducted similar JPB suppression projects in 1993 on the east shore in the Zephyr Cove Resort and Nevada Beach Campground areas through removal of infested trees. Both areas will be monitored in the fall to evaluate treatment efficacy in terms of trees attacked by the 1993-94 generation.

2) JPB Biology (see Appendix I). In the Lake Tahoe area, the JPB usually completes one generation per year which provides time to identify, mark, and remove infested trees. Adult JPB fly and attack new hosts from June to October, depending on weather conditions. Although it is possible in some years that emergence may take place in the fall from trees attacked early in the summer, such occurrences are apparently limited and have not been significant. To be effective, infested trees should be harvested and removed by May 15 of the year following attack.

3) Observed Group Kill Dynamics. JPB-related mortality patterns in the LTBMU vary from older, large, mature, individual trees, to small groups of 2-3 trees, to large group kills of 20-30 pines that occur during outbreaks. Observations in the Basin since the 1980's have shown that large mortality groups tend to be characterized by having several older (1 to 2 years) dead in the immediate vicinity (within 15-20 meters) of the currently infested trees. This suggests that adult JPB, at least in some circumstances, do not fly very far before infesting new hosts. In such situations, the large group kills seem to have developed from a few infested trees over a period of about 3 years. Although not all single tree or small group kills develop into large mortality groups, the implication is that removal of infested trees can prevent additional mortality and potentially prevent the occurrence of large group kills. Efficacy will depend, in part, on how much subsequent mortality occurs from attacks by adults migrating in from outside the treatment area.

B) REGULATION OF STOCKING. The objective of stocking control is to thin overstocked stands and vegetation aggregations to levels appropriate for the site. The intent is to create and maintain healthy vigorously growing trees and stands that can better prevent successful bark beetle attacks. Much of the mortality associated with both the JPB and the fir engraver has occurred in stands/aggregations with basal areas ranging from about 280 sq.ft./ac to >400 sq.ft./ac. Work with pine bark beetles from several areas in the west generally indicates that reducing stocking to about 55% to 75% of normal basal area effectively reduces mortality. This can typically result in stocking levels of between 80 to 140 sq.ft./ac. Interdisciplinary input from a variety of resource specialists is critical to the implementation of this alternative to ensure consideration of effects on overall forest health and diverse management objectives.

C) SANITATION/DISEASE MANAGEMENT. In addition to regulating stocking, removal of selected poorly growing, unthrifty, trees that will not likely respond to thinning should improve the overall vigor of the stand and

reduce the potential for bark beetle attack. This can include removing trees with physical injuries, poor needle retention, diseases (especially dwarf mistletoe- see discussion below), live crowns of less than 20-30% of the tree height, current top-kill of more than 20-30% of the live crown, and current branch dieback that affects at least 50% of the live crown. The decision to remove individual or groups of trees through thinning and/or sanitation for insect and disease management purposes should be made within the context of overall resource management goals and objectives and the desired condition for the area.

D) SLASH MANAGEMENT. Although problems associated with the build-up of pine engravers (Ips spp.) in pine slash has not historically been a problem on the LTBMU, the potential does exist. Several species of pine engravers can attack and breed in fresh, green, slash greater that 2-3" in diameter. Populations that develop in the slash may emerge and attack the tops of nearby trees resulting in top-kill that may predispose trees to subsequent attack by Dendroctonus spp. Ips emarginatus does not tend to build up in slash, but Ips pini does and is present in the Basin. Minimizing the amount of suitable pine engraver breeding habitat (green slash) will prevent population build-up and reduce the risk of attack on standing trees. A discussion of management options for pine engravers is included with the pine engraver biology in Appendix I.

3. Mistletoe Management.

A) DWARF MISTLETOE. Control of dwarf mistletoes in dispersed recreation areas is accomplished mainly through removing heavily infected trees and pruning infected branches from lightly infected trees. Tree removal can be accomplished during sanitation/salvage entries. The objective of control is to reduce the amount of mistletoe to tolerable levels and minimize its spread.

Infections are already so heavy at Secret Harbor, that many trees would have to be removed. Trees with Hawksworth ratings of 5 or 6 are generally expected to die within 10-15 years. If removing heavily infected overstory trees is unacceptable, the longevity of trees may be increased by selectively removing witches' brooms. However, this means that all mistletoe is not removed from pines, and any understory pines will continue to be infected, resulting in reduced growth and increasing chances of eventual attack by the JPB. This is a short-term solution to the problem, and dwarf mistletoe will persist on the site.

A good way to approach dealing with dwarf mistletoe would be to remove heavily infected dying trees during salvage operations. Once this is done, the area can be re-evaluated for further needed treatment such as branch pruning or broom pruning.

B) TRUE MISTLETOE. These mistletoes are difficult to control in incense-cedar because their plants tend to be distributed throughout the crown or concentrated in tree tops, and their seed is spread by birds. Removing the most severely infected, declining, trees may benefit the stand by reducing the amount of mistletoe fruit available

for birds. Removing true mistletoe plants or pruning out infected branched may improve the vigor of affected trees. This is very labor intensive and may be appropriate only for very high value trees.

c. ETHEPHON. This is the chemical name for a product called "Florel" that is registered for use in California to control both dwarf and true mistletoe. Florel is a plant growth regulator and when applied to mistletoe plants, causes those plants to abscise prematurely. Unfortunately it does not affect the internal mistletoe root system, and aerial plants eventually grow back. Long-term control with this product would require periodic re-treatment. Removal of aerial shoots does eliminate the production of seeds, and, therefore, reduces the spread of mistletoe. FPM can provide additional information on this product, its application, and effectiveness.

4. Integrated Alternative/Vegetation Management. The above options are not mutually exclusive. Each should be considered for integration into overall LTBMU vegetation management/forest health activities. Any combination of these alternatives may implemented depending on the objectives for specific stands or areas.

APPENDIX I. Selected Insect and Disease Biologies

Jeffrey Pine Beetle

The Jeffrey pine beetle, Dendroctonus jeffreyi, is the principle bark beetle found attacking Jeffrey pine, Pinus jeffreyi, which is its only host. It is a native insect occurring from southwestern Oregon southward through California and western Nevada to northern Mexico. The beetle normally breeds in slow-growing, stressed trees. The beetles prefer trees which are large, mature, and occur singly rather than in groups. Yet when an epidemic occurs, the beetle may attack and kill trees greater than 8 inches in diameter, regardless of age or vigor. Often the beetle infests lightning-struck or wind-thrown trees, but does not breed in slash.

Presence of the beetle is usually detected when the foliage changes color. The color change of the foliage is related to the destruction of the cambium layer by the beetle. Generally, the top of the crown begins to fade in a slow sequence, with the needles turning from greenish yellow, to sorrel, and finally to reddish brown. By the time the tree is reddish brown, the beetles have usually abandoned the tree. Another sign of beetle attack is large, reddish pitch tubes projecting from the bark of the infested tree.

Jeffrey pine beetles have a distinctive "J" shape egg gallery pattern on the inner bark. Larval mines extend across the grain and end in open, oval-shaped pupal cells. The beetle has a 4 life stages, egg, larva, pupa, and adult. The adults are stout, cylindrical, black, and approximatley five-sixteenths of an inch long when mature. The egg is oval and pearly-white. The larva is white, legless, and has a yellow head. The pupa is also white but is slightly smaller than the mature larva. The life cycle is normally completed in one year in the northern part of the range, but in the southern part, two generations per year may occur. The principle period of attack is in June and July, but attacks also are frequent in late September and early October.

Several other organisms are associated with the attack of the Jeffrey pine beetle. Bluestain fungi, yeasts, and other fungi are transferred into the tree by the attacking adults. The California flatheaded borer, Melanophila californica, the pine engraver, Ips pini, and the emarginate ips, I. emarginatus, may precede the Jeffrey pine beetle or attack the tree at the same time.

Natural enemies, climatic factors, and the tree's own resistance, normally keep the Jeffrey pine beetle population in check. Losses in stands can be kept to a minimum by removing the types of trees the beetle prefers, ie. sick, stressed, wounded. The remaining trees may be protected through a sanitation-salvage cutting, preferably before the beetle can emerge from the tree. Other options may be to fell the tree and burn it, peel the bark off or spray the tree. If the beetle has reached the pupal stage, peeling the bark to expose the insect will be ineffective.

Fir Engraver

The fir engraver (Scolytus ventralis) attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber are susceptible. Attacks can cause patch-killing of cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in firs that have been weakened by root disease, dwarf mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green fir slash from June to September; larvae, pupae, and adults over-winter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the year usually do not fade until the following spring or summer, often after the beetles have emerged.

Western Dwarf Mistletoe

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts. Western dwarf mistletoe (A. campylopodum) infects principally ponderosa, Jeffrey, and knobcone pines, and occasionally Coulter and lodgepole pines.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occasionally vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of Digger pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached, and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

True Mistletoe

True, or leafy, mistletoes are parasitic plants in the genus Phoradendron, with mature shoots more than six inches long. The size of their shoots help to distinguish them from dwarf mistletoes. The foliage of true mistletoes may be leafy or scaly, and their fruit is a round berry. They are common parasites of hardwoods but also infect several species of conifers in California, primarily white fir, incense-cedar, and western juniper. They obtain water and minerals from their host.

True mistletoes are spread mainly by birds, including robins, bluebirds, thrushes, and cedar waxwings. Birds feed on the berries, digest their pulp, and excrete the living seed, often depositing them onto susceptible trees. A viscous coating and hair-like threads on the outer surface of the seeds attach them firmly to twigs and branches, where they germinate and infect host tissues.

Young or small trees are seldom infected by true mistletoe. In nearly all cases, initial infection occurs on the branches of larger or older trees because birds prefer to perch in their tops. Severe buildup of mistletoe often occurs in an already infected tree because birds are attracted to and may spend prolonged periods feeding on the mistletoe berries.

True mistletoes are often considered to be curiosities, but they can be serious pests where individual trees are of high value, as in yards, parks, and campgrounds. Heavily infected trees are weakened, reduced in growth rate, and sometimes killed. Weakened trees are predisposed to attacks by insects and often die during drought or other periods of stress. Branches and tree tops heavily laden with true mistletoe often break during wind storms, increasing the hazard to people and property in campgrounds and other developed sites.

Mountain Pine Beetle

The mountain pine beetle, Dendroctonus ponderosae, attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 4 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is the general rule, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine.

Attacks may extend from the root collar up to near the top. Pheromones released during a successful attack may attract enough beetles to result in a group kill. Pitch tubes and red boring dust in bark crevices or on the ground indicate successful attacks.

The adults bore long vertical egg galleries and lay eggs in niches along the sides of the gallery. A "J"-hook is common at the lower end of the gallery. The hatching larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

The sapwood of successfully attacked trees soon becomes heavily bluestained. The bluestain fungi probably aid in overcoming the defenses of the host tree.

Natural factors affecting the abundance of the mountain pine beetle include low winter temperatures, nematodes, woodpeckers and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and mortality increases. Relieving stress by thinning dense stands can prevent some group kills. Individual high value trees undergoing temporary reversible stress may be protected from attack by application of insecticide to the bole.

Elytroderma Needle Disease

The fungus Elytroderma deformans causes the most serious needle disease of ponderosa and Jeffrey pines in California. Occasional hosts include lodgepole, knobcone, Coulter, and pinyon pines. Unlike other needle diseases, Elytroderma infects twigs and branches systemically, allowing continued reinfection of a host's new needles even under adverse environmental conditions. Elytroderma impact is most severe in recreation forests, where the unsightly appearance of infected trees and occasional mortality can degrade the visual quality and health of a stand.

Fungal fruiting bodies (hysterothecia) release spores from infected needles in late summer and early fall. Spores are windborne to susceptible hosts and, if environmental conditions are suitable, they germinate and infect the current year's needles. Initially, the fungus grows through the needle and into the twig without killing the needle. The following spring, infected needles die and turn a conspicuous red-brown. Infected branches take on a characteristic appearance, with current year's needles looking green and healthy while the one-year-old, infected needles are bright red-brown. Long, narrow, dull black fruiting bodies form on all surfaces of the dead needles and mature later in the summer, completing the infection cycle.

Fungal mycelium within the twigs spreads into the growing tips and buds, deforming future branch growth. As a result, infected branches have a broomed appearance similar to that caused by dwarf mistletoes. However, Elytroderma brooms are distinguished by several characteristics: the red-brown color of one-year-old needles in spring and early summer; fruiting bodies scattered over the needle surface; resinous, brown necrotic lesions

who may extend from the root collar up to [illegible] the
[illegible] chafing [illegible] [illegible] [illegible] [illegible] enough
[illegible] will [illegible] [illegible] [illegible] [illegible] in bark [illegible]. [illegible]
[illegible] [illegible] [illegible] cause [illegible].

[illegible] [illegible] long [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] of the gallery. [illegible] [illegible] [illegible]
[illegible] hatching larvae feed in [illegible] [illegible] [illegible] [illegible] gall
[illegible] small pupal cells [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] into adults.

[illegible] period of successfully attack [illegible] [illegible]
[illegible] [illegible]: trees probably old [illegible] [illegible] [illegible]

[illegible] factors affecting the [illegible] [illegible] [illegible]
[illegible] temperature, humidity [illegible] [illegible] [illegible] [illegible]
[illegible]. [illegible] and susceptibility [illegible] [illegible] [illegible]
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[illegible] and [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] prevent [illegible], [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] to the host.

Needle Diseases

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[illegible] the Jeffrey pines [illegible] California. [illegible] [illegible]
[illegible], [illegible], [illegible] the pinyon pines. [illegible] [illegible]
[illegible] infects twigs and branches [illegible] [illegible]
[illegible] infection of a host's new needles [illegible] [illegible] [illegible]
[illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] appearance of infected trees and [illegible] [illegible]
[illegible] the wood quality and health [illegible] [illegible].

Fungal fruiting bodies (hysterothecia) release spores from infected needles
[illegible] and early fall. Spores are windborne to susceptible hosts
[illegible] if environmental conditions are suitable, they germinate and infect the
[illegible] year's needles. Initially, the fungus grows through the needle and
[illegible] without killing the needle. The following spring, infected
[illegible] and turn [illegible]. Infected branches take on a
[illegible] appearance, with current year's needles looking green and
[illegible] the [illegible], infected needles are bright red-brown.
[illegible] [illegible] [illegible] on [illegible] [illegible] of the [illegible]
[illegible] summer, completing the infection cycle.

[illegible] [illegible] upwards into the growing tips and [illegible]
[illegible]. As a result, infected branches have a
[illegible] [illegible] by dense [illegible]. However,
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] summer; [illegible]
[illegible] [illegible] [illegible] [illegible]

in the inner bark of twigs and branches infected for three years or more; and, a lack of mistletoe shoots or basal cups.

Elytroderma disease kills one-year-old needles prematurely and deforms infected twigs and branches. Generally, pines are little affected if fewer than 40 percent of the twigs are infected. The disease seldom kills mature trees directly, but moderate-to-severe infection can predispose them to bark beetle attack. The disease is most severe on seedlings, saplings, and poles that are suppressed or have thin crowns. Disease outbreaks are uncommon, but once started, the disease can persist for many years, particularly on moist sites.

Pine Engraver Beetles

Pine engraver, Ips spp., attacks have been recorded on most species of pines in California. These beetles kill saplings, poles and sawtimber up to about 26 inches dbh and the tops of even larger trees. Attacks on live trees are usually limited to trees which are suppressed, or stressed by dwarf mistletoe, root disease, drought, fire or the attack of other insects. If fresh slash is available in the spring, pine engravers may build up in an area and cause localized mortality or top killing by mid-summer.

Attacks are made with the coming of warm weather in the spring. Attacking males bore nuptial chambers in the inner bark and release a pheromone which attracts other beetles to the attack site. If many beetles are attracted, they may attack nearby trees and cause a group kill. Within a day or two of the attack by the male, two to five females enter the nuptial chamber and after mating, each female bores an individual egg gallery which lightly scores the sapwood. The size and pattern of the combined gallery pattern is often diagnostic of the species of Ips involved. The galleries are kept open by beetles pushing boring dust out through the entrance hole. Red boring dust collecting in bark crevices or spider webs is diagnostic of a successful attack. Eggs are laid in niches along the sides of the galleries. Larvae hatch from the eggs and feed in the phloem. They eventually pupate in cells at the end of their larval mines and transform to adults.

A new generation is produced in as little as 6-8 weeks in the spring to 4-6 weeks in mid-summer (August). Thus, several overlapping generations per year may be produced. The winter may be passed in any of the life stages of larvae, pupae, or adults, depending upon which Ips species is involved.

Outbreaks in standing, healthy trees are sporadic and of short duration, and are often associated with some temporary stress or shock afflicting the host species, such as drought or logging disturbance. Tree killing frequently occurs where green pine slash, which serves as breeding habitat is left untreated during spring and summer. To be suitable as pine engraver breeding habitat, pine slash must have bark from 1/8 to 1 inch thick (usually 3 to 26 inches diameter), must have succulent cambium and must remain moderately cool during the development period.

Fresh pine slash caused by thinning, dwarf mistletoe control work, construction or winter storm breakage can be modified in a number of ways to

make it unsuitable for pine engraver breeding. One approach to minimizing damage is to schedule slash-generating activities mostly between mid-July and late-December, when the slash has a high probability of drying out, heating up, or spoiling before the beetles can complete their development. Utilization of the cut material to the smallest possible diameter will minimize the amount of breeding material available to engraver beetles. If green pine slash must be created during the sring and early summer, slash treatments are available to prevent the buildup of pine engraver populations. Because pine engravers can complete their development in about a month under ideal conditions, treatment should be carried out soon after cutting to be effective.

Slash treatment methods which generally work well include chipping, lopping and scattering slash in sunny areas to heat it up, crushing or mashing slash with logging equipment to make it unsuitable for pine engraver breeding, or piling and burning the slash within a month of cutting. Broadcast burning the slash might work if it could be done without damaging the residual stand. A method which has worked during the summer in hot climates is to pile slash in a sunny area and tightly cover the pile with clear plastic. If the temperature under the bark of slash in all parts of the pile reaches 120^{o}F, all brood currently in the pile will be killed. Lower temperatures will not be effective and, where successful, this method will not prevent reinfestation of slash piles. Because most pine engraver attacks occur within a quarter-mile from the location where the beetles emerged, high value pines can be given some protection by removing fresh pine slash to areas which do not have pines.

Two practices which should generally be avoided are piling fresh pine slash without further treatment, and allowing slash to touch or remain near valuable leave trees.